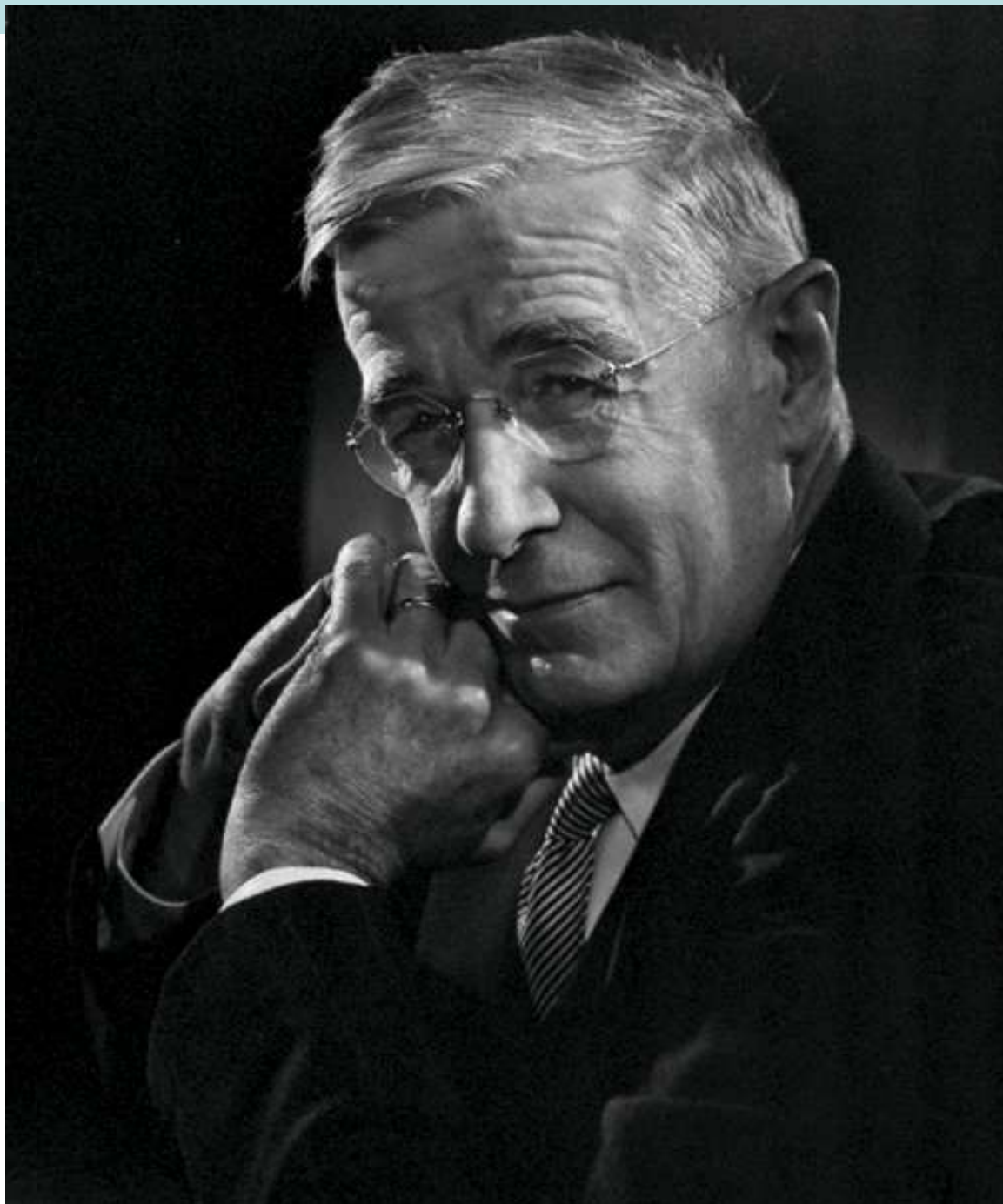
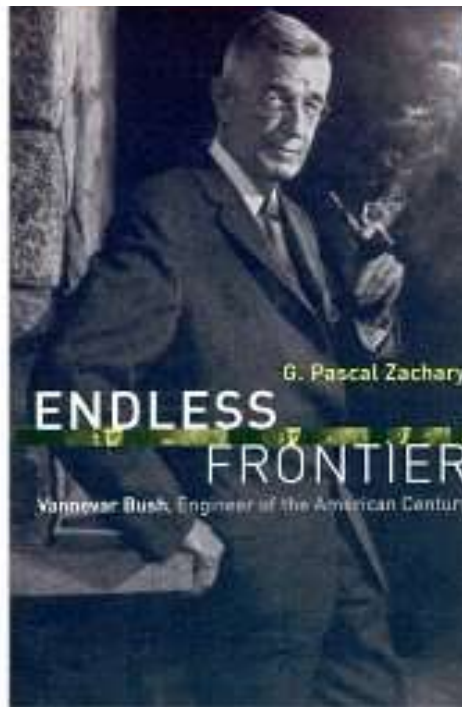


Frontiers



The US as a Frontier Society
Frederick Jackson Turner







Binnig and Rohrer, 1980's. STM – the key tool for nanoscience



National Nanotechnology Initiative at Ten:

NANOTECHNOLOGY INNOVATION SUMMIT

DECEMBER 8-10, 2010
GAYLORD CONVENTION CENTER
WASHINGTON, DC

THANKS



Center for Nanofabrication
And Molecular Self-Assembly



Institute for Bio-
Nanotechnology
In Medicine



Center for Nanoscale
Materials

International Institute for Nanotechnology

Chad Mirkin



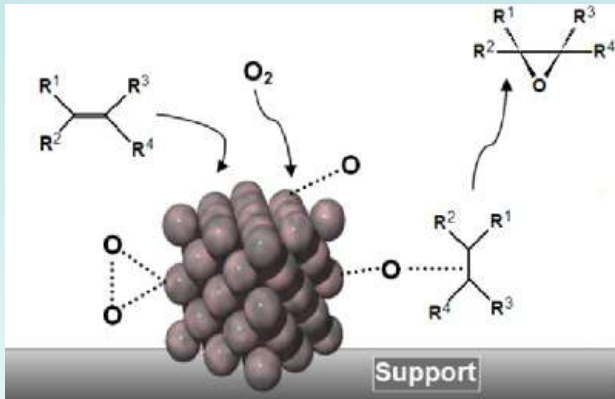
Gary Rubloff



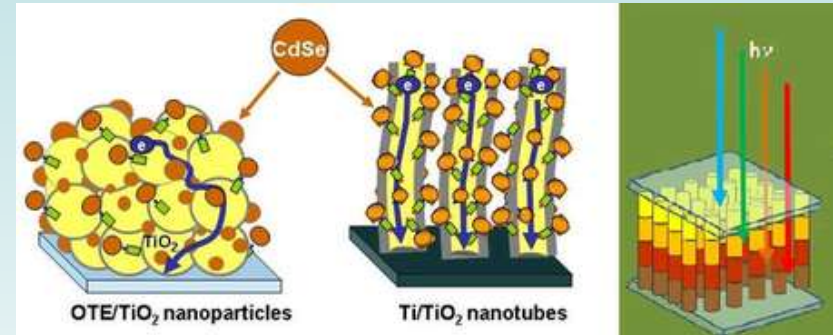
Nanotechnology: Frontier Grand Challenges

Complex and Useful Function From Building Blocks and Extended Architectures

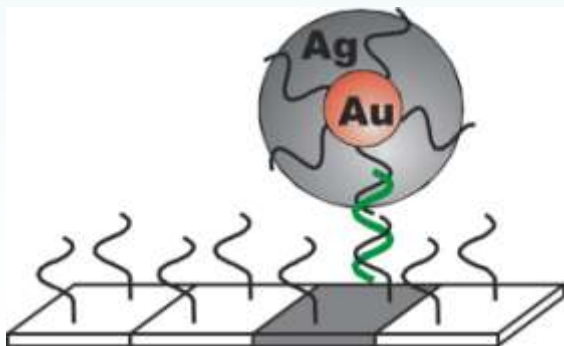
Materials and Catalysis



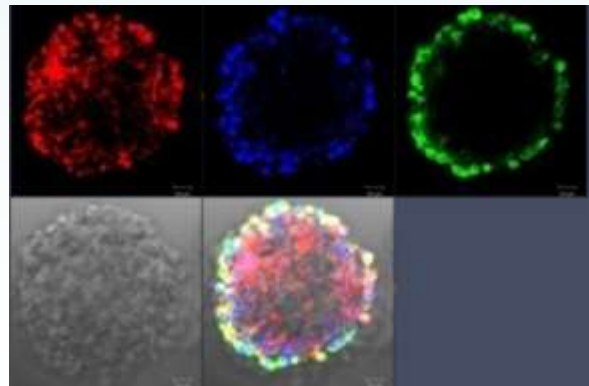
Energy Harvesting, Storage



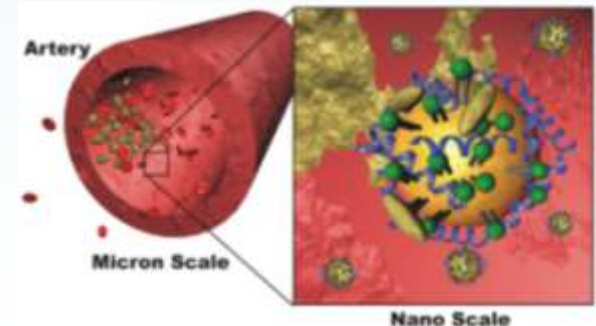
Molecular Diagnostics



Gene Regulation



Therapeutics



BIG PROBLEMS? CHALLENGES IN THE SOCIETY

Renewable energy

Capture

Storage

Affordable health care

Diagnostic

Therapeutic

Security

Economic

Physical

Energy

Sustainability

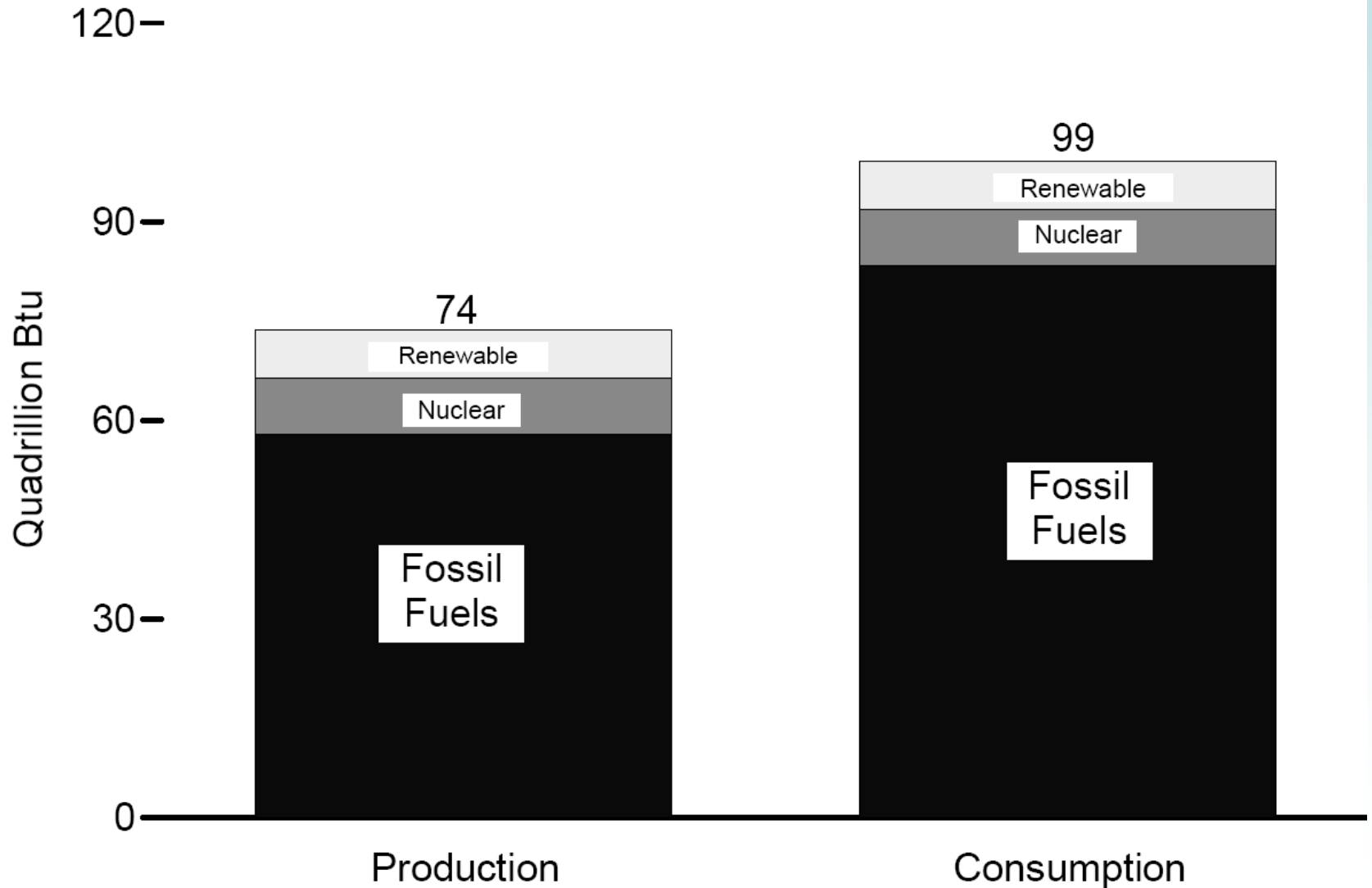
Carbon management

Climate change

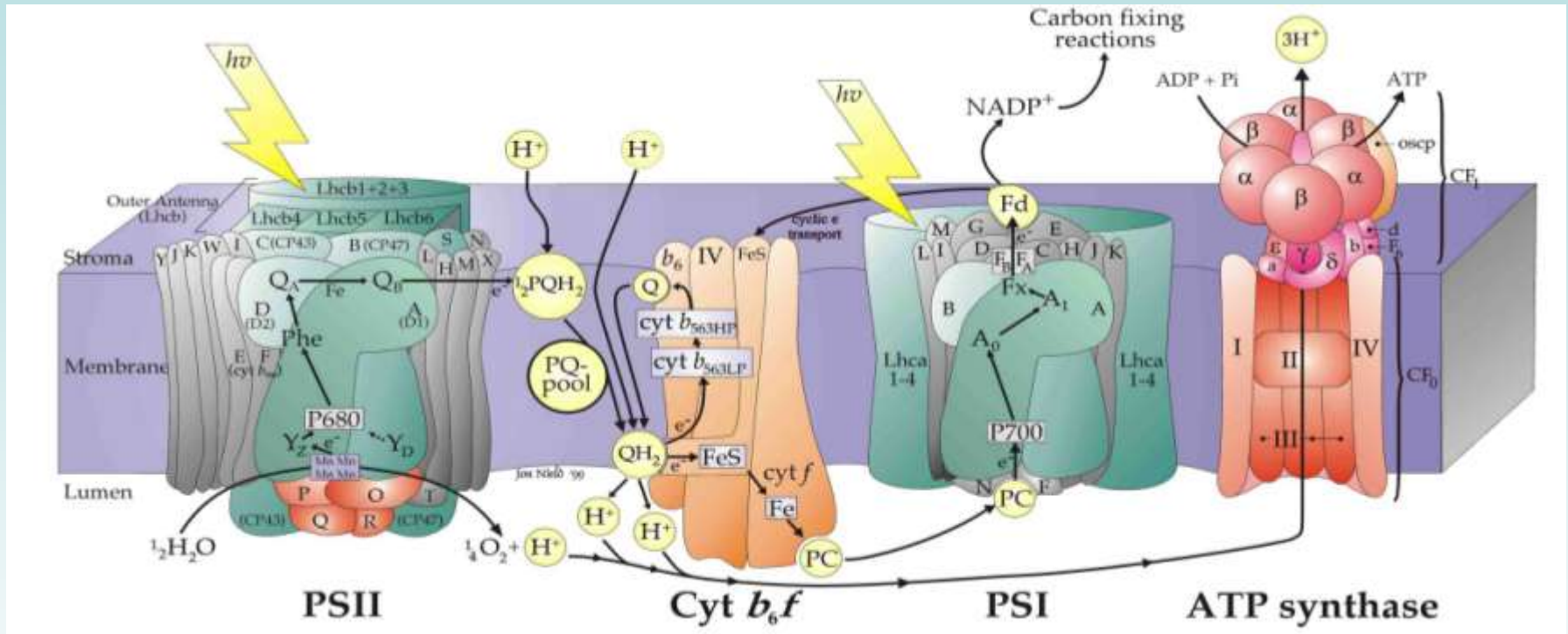
Employment

USA - Total Energy

Production and Consumption, 2008



Photosynthesis

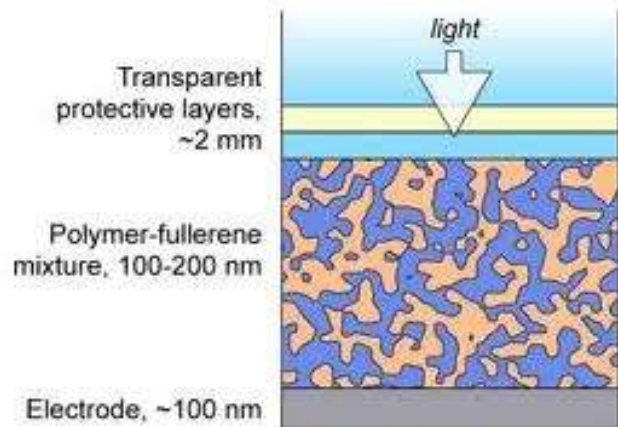


Challenge: Mimic assembly, function, regulation, and maintenance of the **multiple nanostructure** photosynthetic apparatus.

→ improve efficiency and maintenance



Energy capture



Konarka



Nanobattery: Cathode made of ***nanoscale*** particles of LiFePO_4

Energy storage

BIG PROBLEMS? CHALLENGES IN THE SOCIETY

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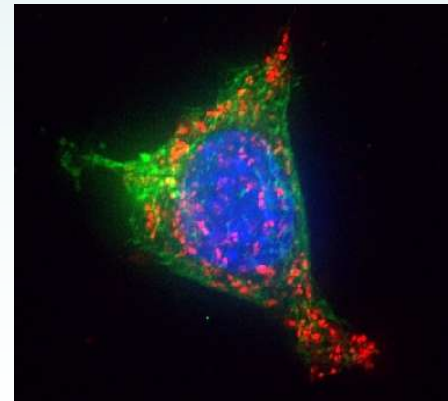
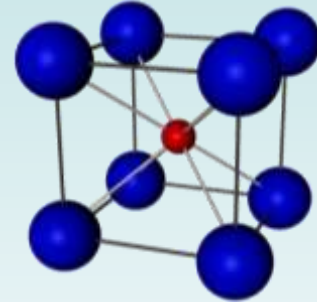
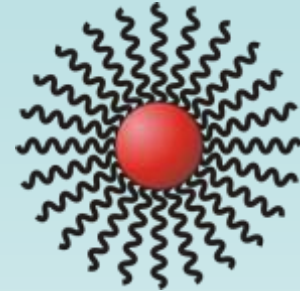
Carbon management

Climate change


Employment

The Grand Challenges in Nanotechnology

- **Nanoscale Building Blocks and Tools for Miniaturization**
- **Controlled Assembly of Such Building Blocks into Hierarchical Structures**
- **Complex and Useful Function From Building Blocks and Extended Architectures**



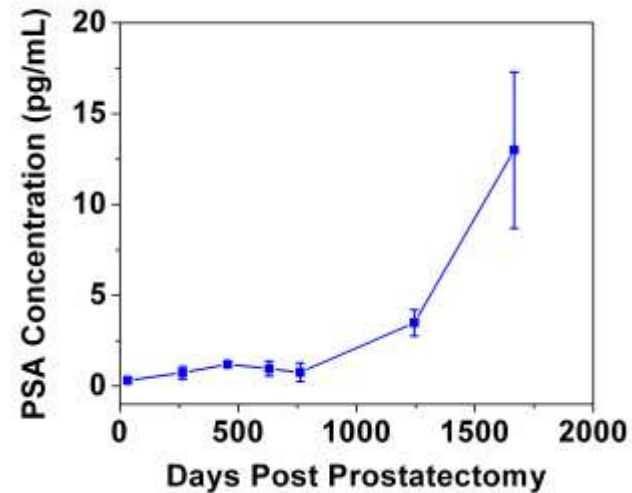
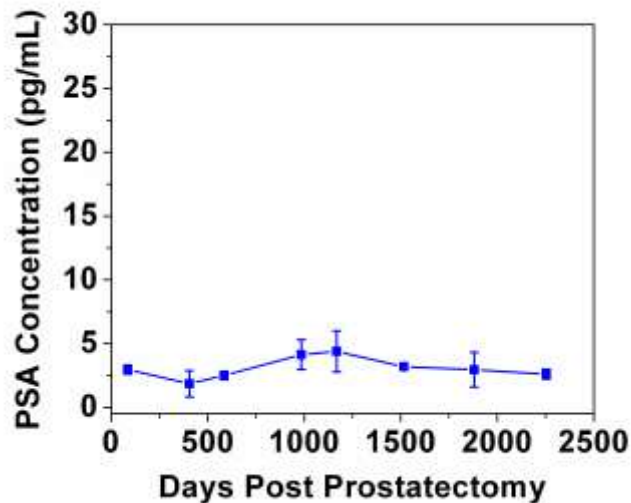
Diagnostics -Field Defining Technologies



Concentration	Molecule/Drop	Detection/ Targets/Disease
10^{-3} - Millimolar	Quadrillions	Colorimetric/ Enzymatic Chemistry Blood Sugar (Diabetes)
10^{-6} - Micromolar	Trillions	
10^{-9} - Nanomolar	Billions	ELISA & Chemiluminescence Troponin, CK-MB, BNP, β HCG
10^{-12} - Picomolar	Millions	
10^{-15} - Femtomolar	Thousands	Bio-barcode Technology Alzheimer's Disease, Mad Cow, Ovarian, Breast, and many other cancers, Pulmonary Disease, Cardiovascular Disease
10^{-18} - Attomolar	Tens	
10^{-21} - Zeptomolar	<1	

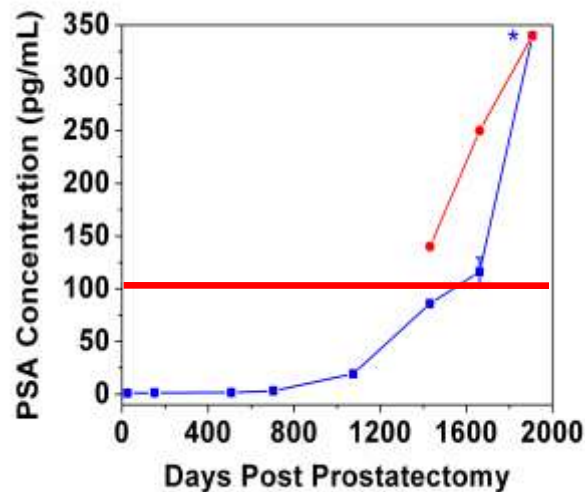
Bio-barcode Nanoassay Detects PSA Levels Undetectable by ELISA

ELISA Level of Detection 100 pg/mL

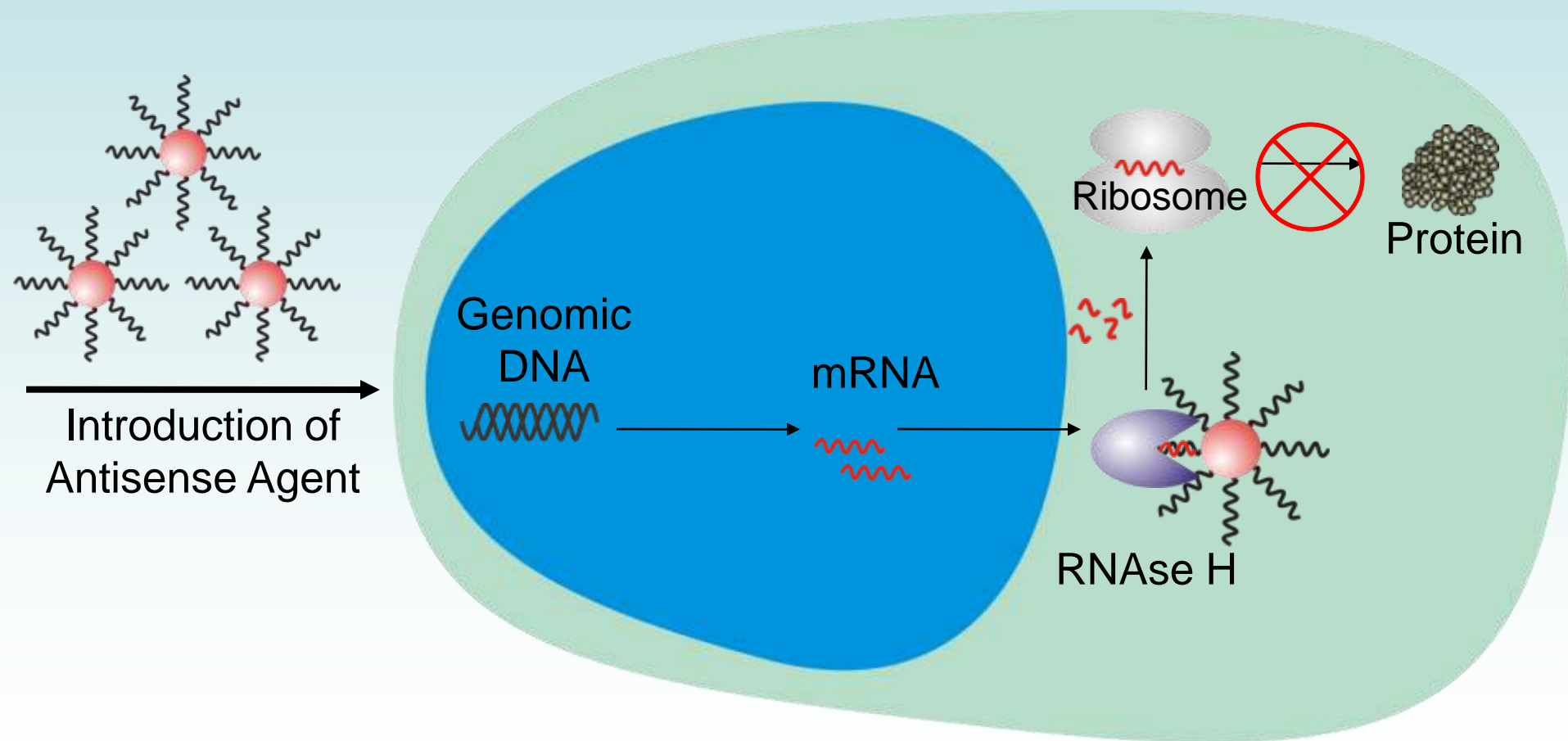


Blue: biobarcode assay

Red: ELISA

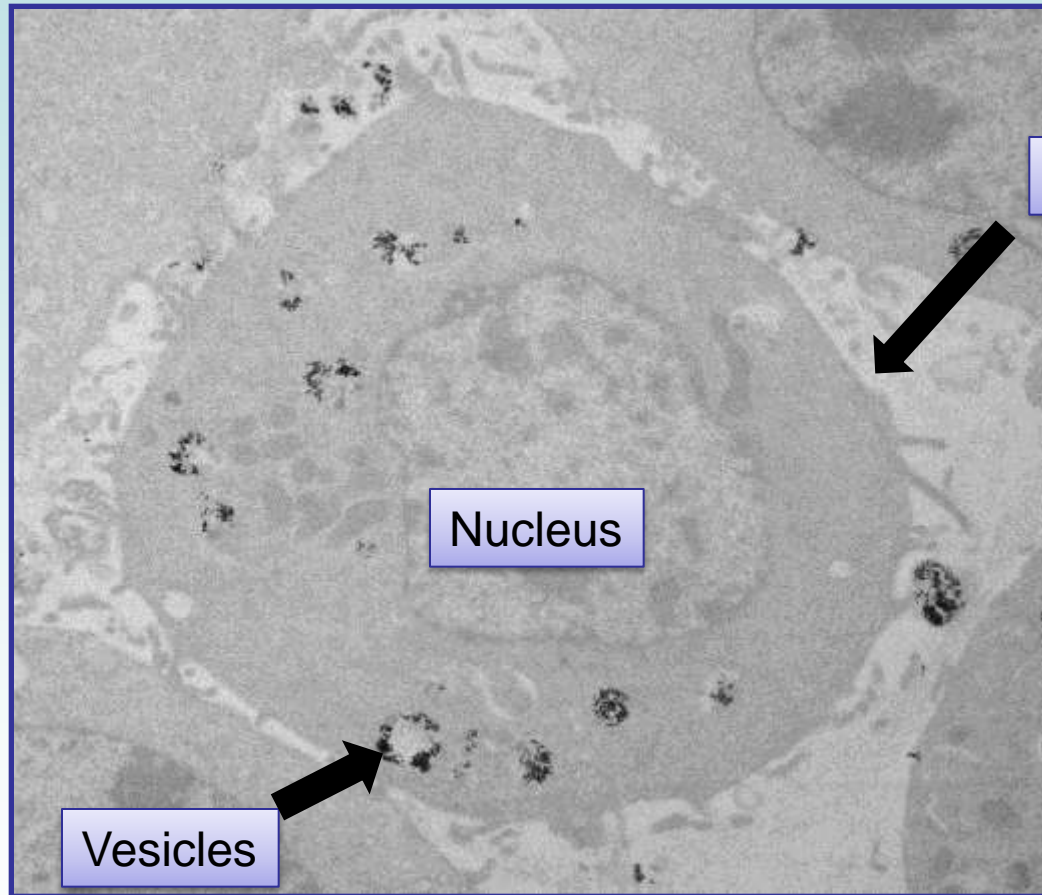


Polyvalent Oligonucleotide-Functionalized Nanoparticles As Antisense Agents?



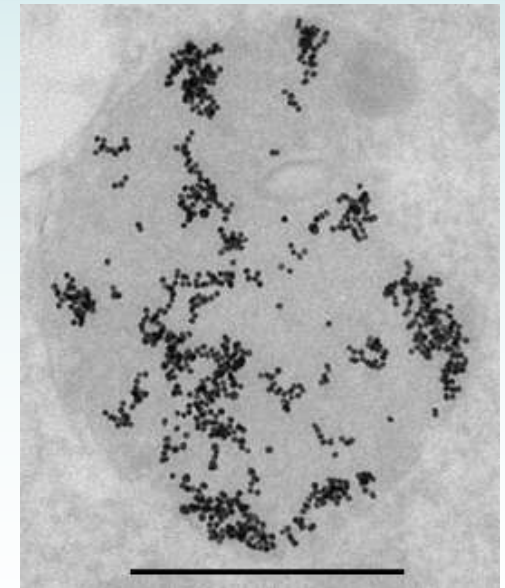
Cellular Entry

Entry Appears to be by Endocytosis



TEM Image of Cell Showing Particle Localization 6 hr Post Transfection

Individual Vesicle



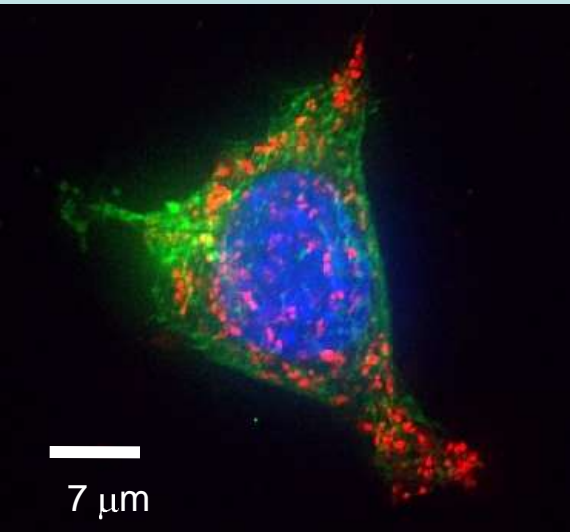
500 nm

60,000 X Magnification
C166 (mouse endothelial) cells

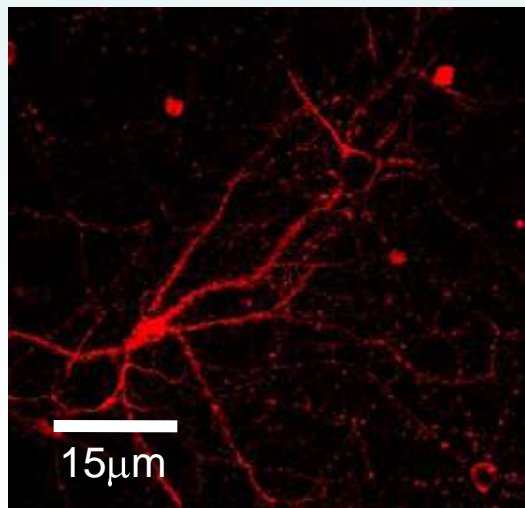
Enter All Cell Lines and Primary Cells Studied

Cell Lines

- Breast (SKBR3, MDA-MB-231, AU-565)
- Brain (U87, LN229, U118)
- Bladder (HT-1376, 5637, T24)
- Colon (LS513)
- Cervix (HeLa, SiHa)
- Skin (C166, KB, MCF 10A)
- Kidney (MDCK)
- Blood (Sup T1, Jurkat)
- Leukemia (K562)
- Liver (HepG2)
- Kidney (293T)
- Ovary (CHO)
- Fibroblast (NIH3T3)
- Macrophage (RAW264.7)



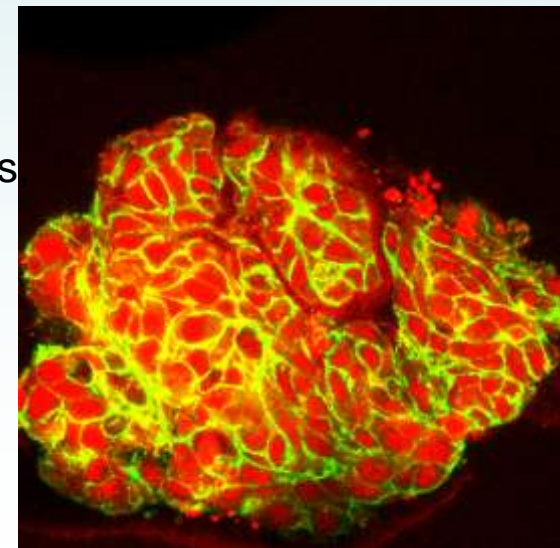
HeLa Cells



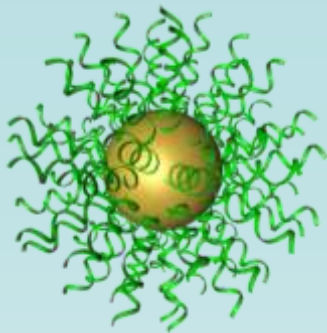
Rat Hippocampal Neurons

Primary Cells

- Brain (Rat Hippocampus Neurons, Astrocytes, Glial Cells)
- Bladder
- Blood (Mouse Erythrocytes, PBMC, T-cells)
- Pancreas (Mouse Beta Islets)
- Skin (mouse)



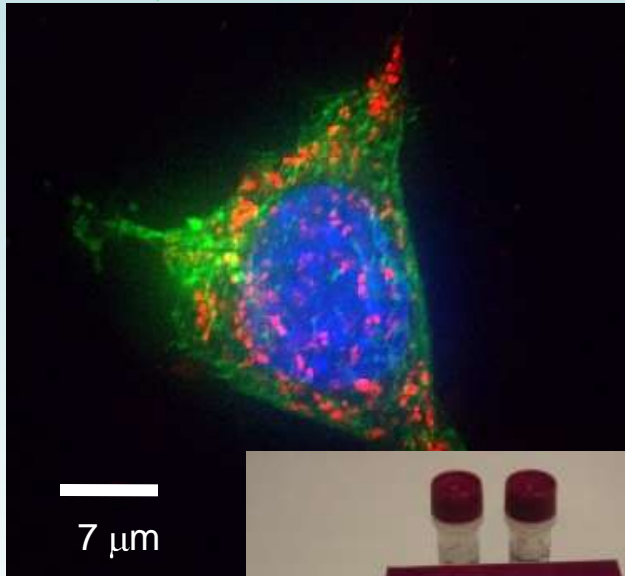
Epithelial Tumor Model



Gene Regulation Platform

Key Advantages

- *A unique method for delivering large amounts of genetic material into cells as therapeutic agents*
- Effective across numerous cell and tissue types (50+ cell types have been demonstrated to date)
- Stable, long-lasting intracellular activity
- Efficacious and non-toxic in animals
- Applicable to many forms of cancer, skin disorders, neurological diseases, and more
- Immediately useful as research product (Omnifectin™) with \$100MM potential



Carrier-Free Gene
Regulation
Constructs

- 
- *2 therapeutic partnerships at work-plan definition stage*
 - *Substantial Omnifectin™ development, product marketing efforts*



BIG PROBLEMS? CHALLENGES IN THE SOCIETY

Renewable energy

Capture

Storage

Affordable health care

Diagnostic

Therapeutic

Security

Economic

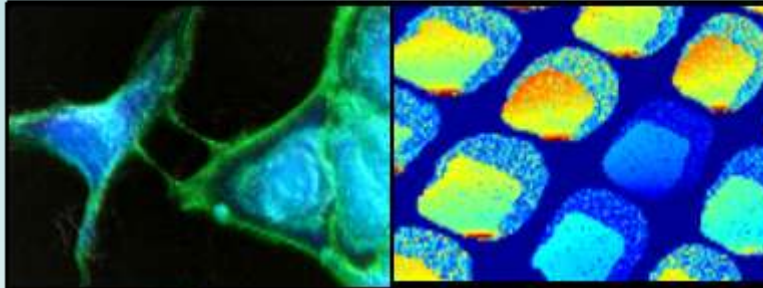
Physical

Energy

Sustainability

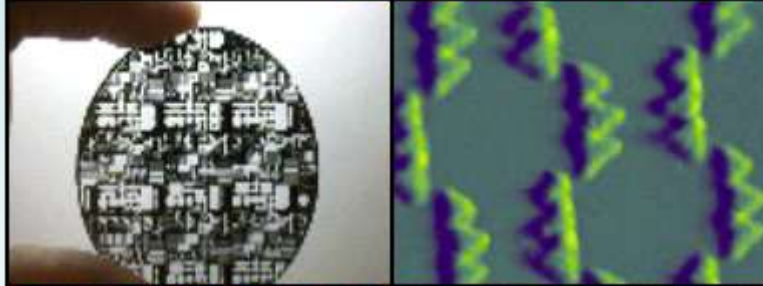
Nanotechnology Research Areas That Show Promise For Innovation

**Biomedical Applications
Diagnostics, Imaging,
Therapeutics**



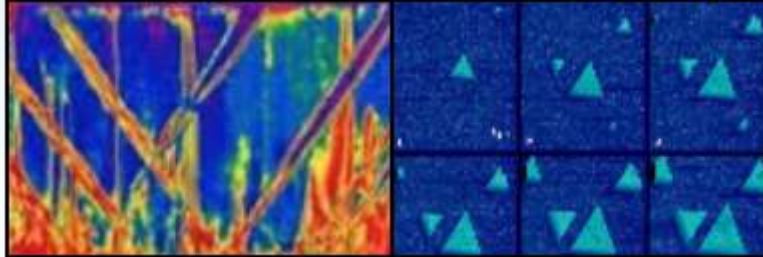
**Photonics and
Magnetics**

Electronics



**Nanolithography/High
Resolution Printing**

Energy Applications

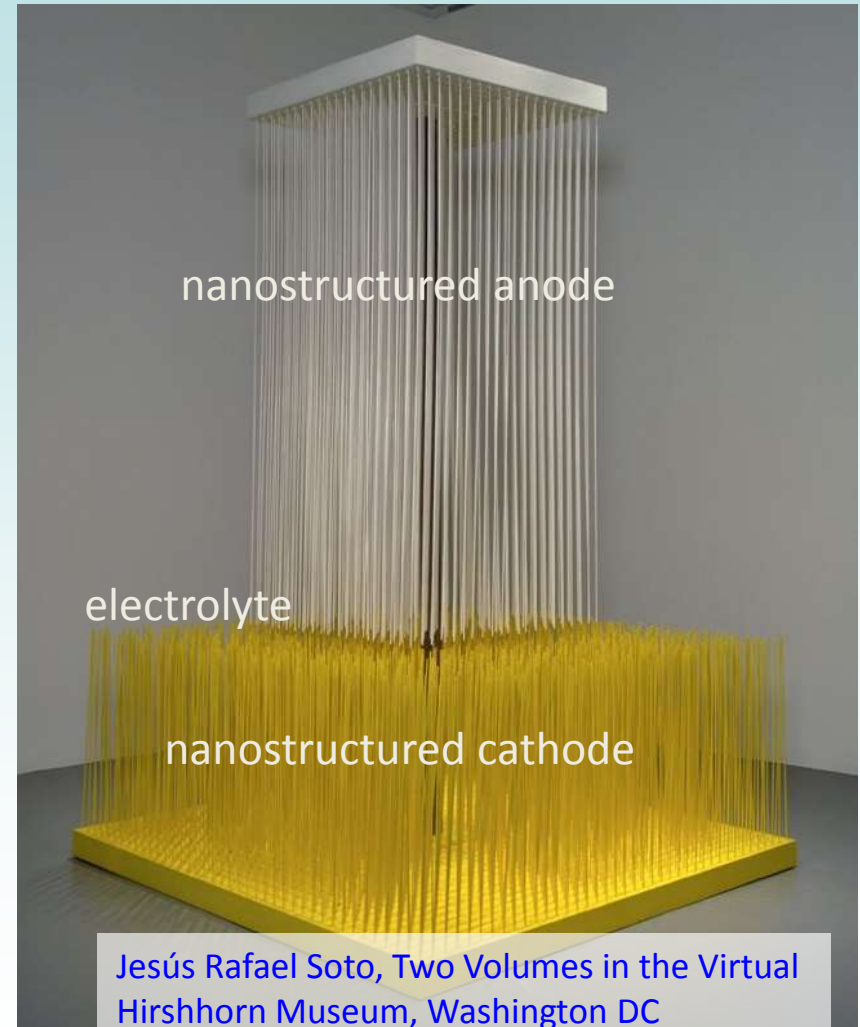


**High Performance
Nanostructures and
Materials (Catalysis,
Environmental
Diagnostics and
Remediation)**

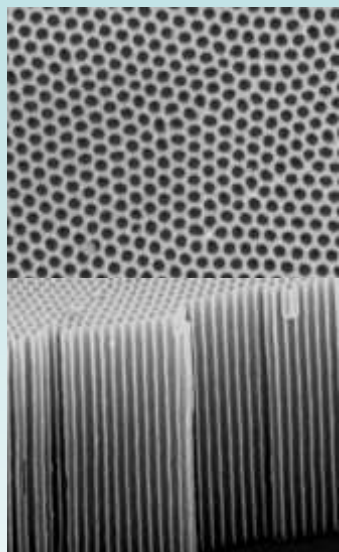


Why Nano?

- Nanostructure synthesis
 - Dimensional control
 - Massive arrays
 - Extremely high aspect ratios (depth/width)
- Large surface area
 - ➔ easy access to charge storage materials
 - ➔ high power
- Thin material layers
 - ➔ fast transport into charge storage materials
 - ➔ mechanical flexibility to accommodate charge cycling
- Large electrode volume
 - ➔ high energy density

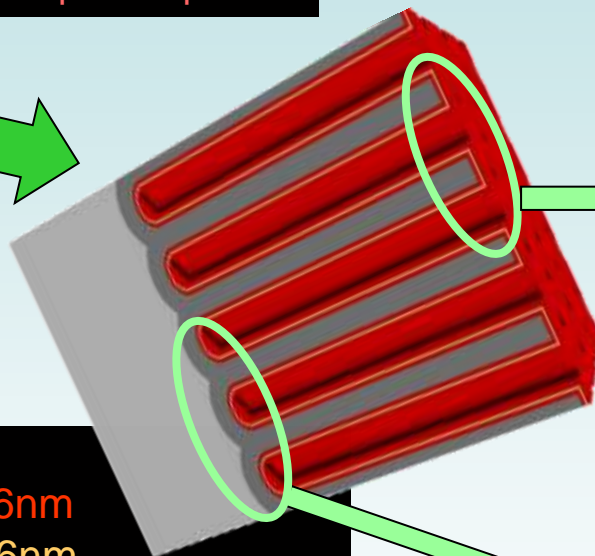
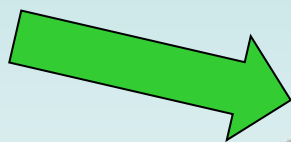


AAO-ALD for MIM Electrostatic Supercapacitor



AAO nanopores

60nm dia, 1-10 μ m deep



ALD MIM layers:

Top electrode: TiN 12.6nm

Dielectric: Al_2O_3 6.6nm

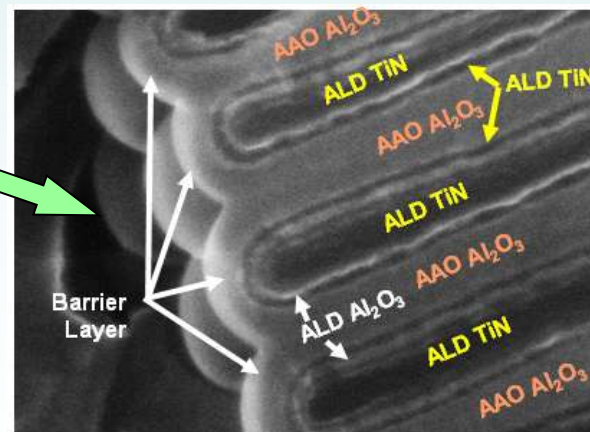
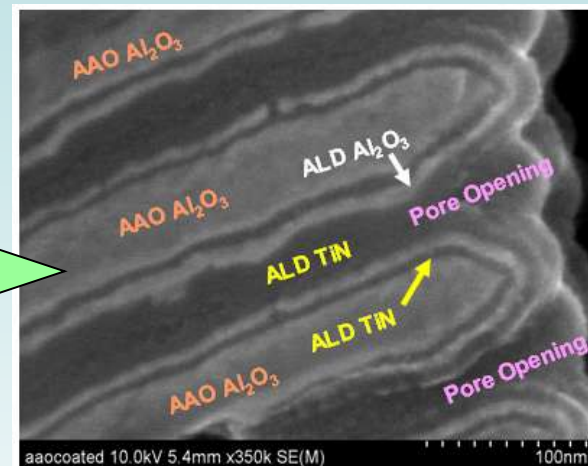
Bottom electrode: TiN 5.6nm

Aspect ratios 200-1000 (depth/width)

ALD conformality >93% in all layers

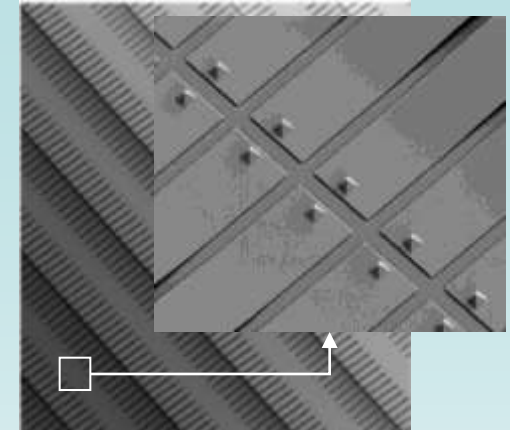
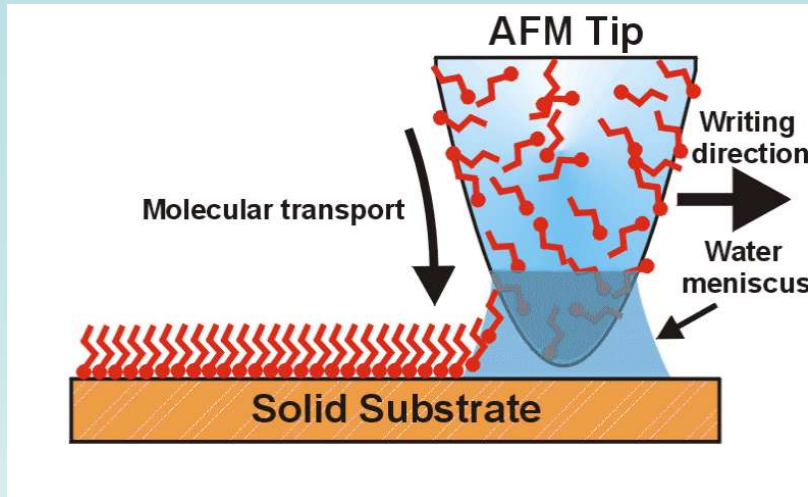
100 billion nanocapacitors per square inch

SEM images



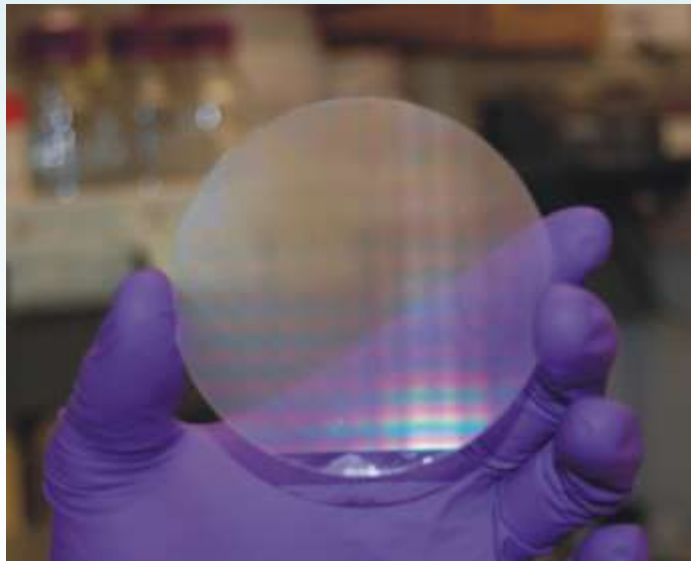
Rubloff-Lee groups

Manufacturing: Massively Parallel Capabilities

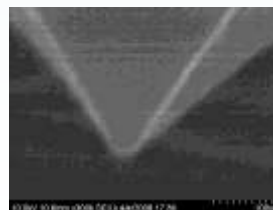
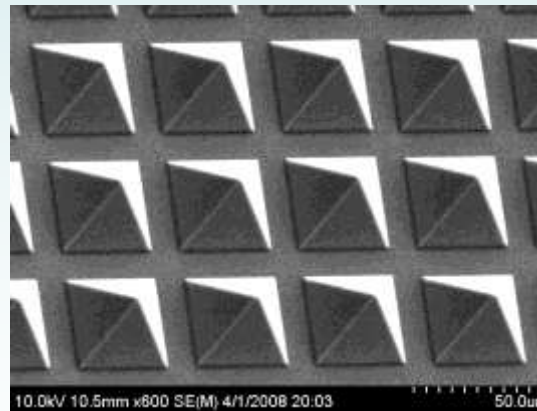


1.3 Million Probe 2-D Passive Array

Make **arbitrary** circuits/patterns – Dip Pen Nanolithography



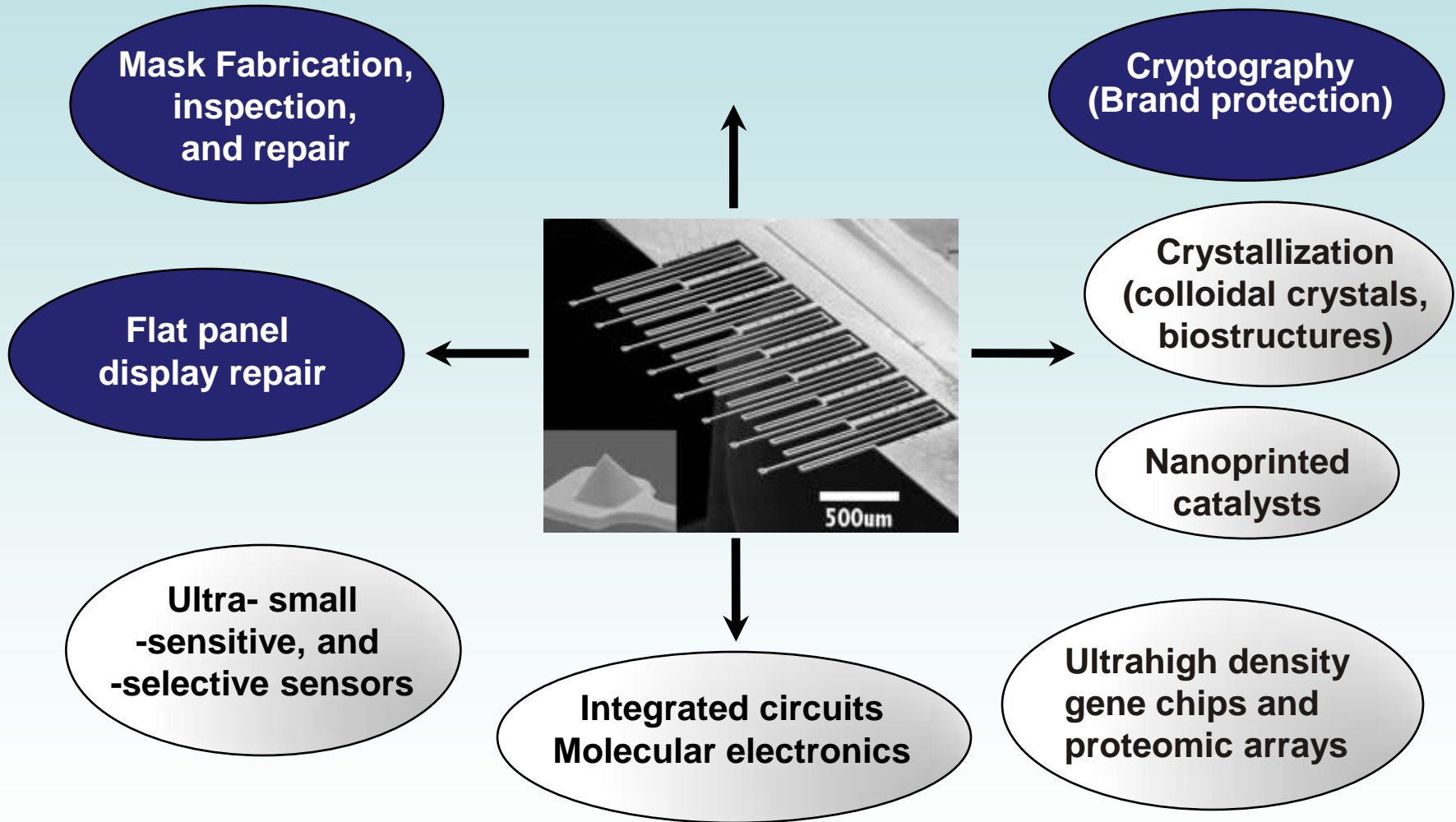
11 Million Pen Array



**Tip size:
60 10nm**



DPN Applications



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Physical

Energy

Sustainability

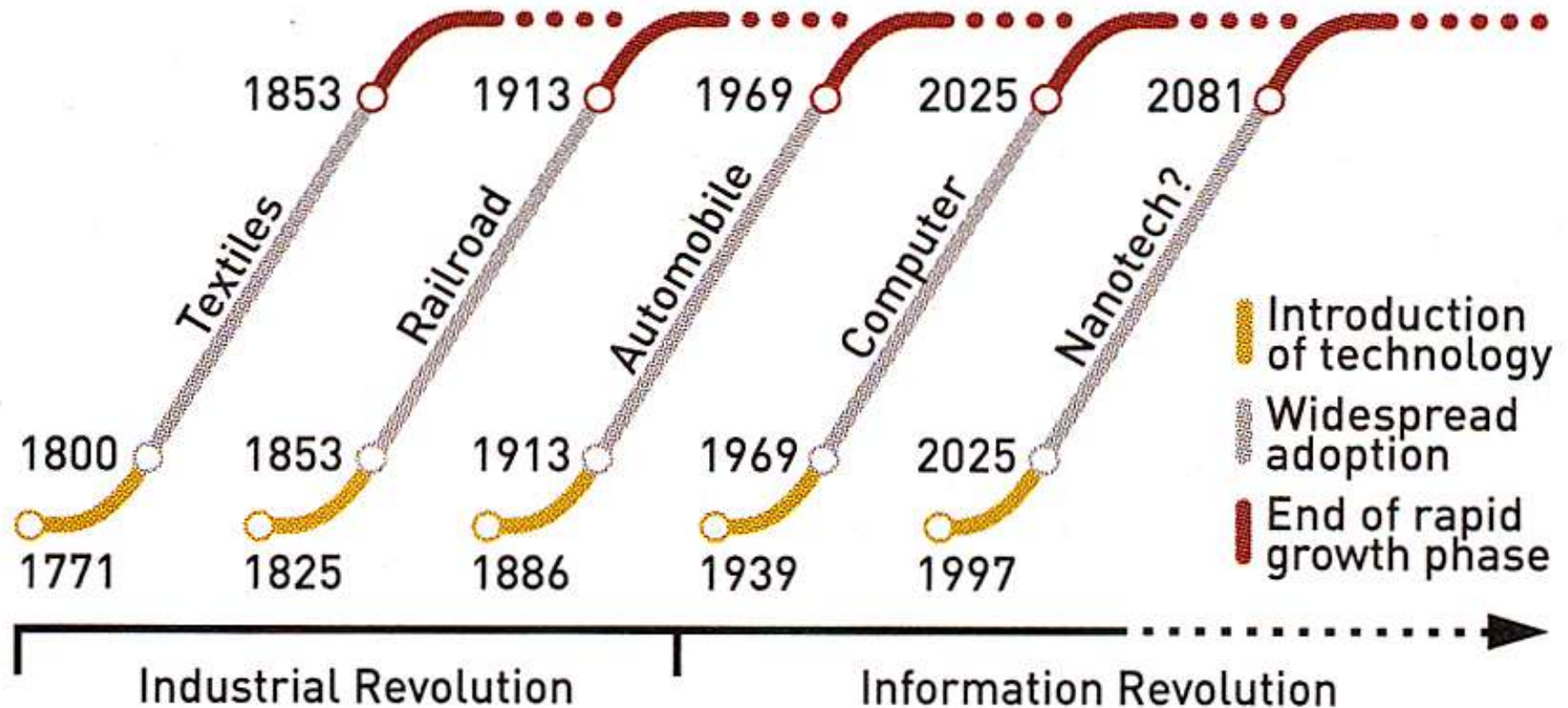
Employment/education





REVOLUTIONARY FORCES

Basic advancements in science and technology come about twice a century and lead to massive wealth creation.



SOURCE: Norman Poire, Merrill Lynch

Red Herring, 2003

**There is more day to dawn
The sun is but a morning star**

H. D Thoreau